parameters should be reported together for each reported condition. The throughput of the system is defined as the amount of volume sorted in a given time period. The throughput (Q_m) can be given by $Q_m = Q_\Phi$, where Q is the volumetric flow rate, and Φ is the volume fraction of particles input. Additionally, for most systems increasing the device footprint (i.e. parallelization) increases the device throughput linearly. Therefore the throughput per unit area (mL hr^{-1} cm^{-2}) is a useful measure. In one exemplary system, a throughput of 0.6 mL hr^{-1} was achieved with a device area of 2.5 cm^2. Enrichment ratio is defined as the number of selected particles to unselected particles in the filtrate divided by the initial fraction of selected/unselected particles ($s_f/u_f/s_i/u_i$). Thus, enrichment is dependent on depleting the unselected particles but also on maintaining high yields of the selected particles (s_f/s_i). In the systems described herein, enrichment ratios of 8-∞ corresponded to yields of 60%-5%, after a single pass. An enrichment ratio of ∞ corresponds to zero unselected particles present in the filtrate. The separation resolution is a measure of the size difference required for successful separation (a smaller number is better). It is defined as the size difference required for >90% depletion of the unselected particles, divided by the fractional yield of selected particles. Using FIG. **24**B, in one embodiment, a single pass provides for 1 log enrichment in separation of particles with 3-μm resolution.

Example 16

[0240] Referring now to FIGS. **32**A-**32**B, in one embodiment, a system is provided for focusing particles above a certain size while smaller particles remain unfocused for a given geometry. To investigate the relationship between particle size and channel geometry, a mixture of 10-μm and 2-μm beads were flown at varying flow rates through a channel having an expanding spiral configuration. As can be seen in FIGS. **32**A and **32**B, the smaller 2-μm particles remain unfocused, while the 10-μm particles quickly focus and remain focused at different turns of the spiral. We tested different flow rates and the 2-μm particles remained unfocused irrespective of flow rate, supporting the theory of a optimal particle size to channel geometry below which no focusing can occur. High-speed camera result shown in FIG. **32**B illustrate that the larger 10-μm particles are focused in a single stream very close to the inner wall, while the 2-μm particles are scattered all over the channel.

[0241] The larger 10-μm particles remain focused over a wide range of R_c due to the dominant lift forces balancing the secondary Dean flow pushing the particles to the outer wall. The larger 10-μm particles are focused closer to the inner wall, enabling almost 100% recovery of the enriched 10-μm particles fraction. The focusing of particles is not limited to rigid particles, but also non-rigid biological material. Cells were also successfully focused to single streams, opening up opportunities for high throughput processing of biological components.

Example 17

[0242] To test the effect of R_c on the lateral positional displacement of focused particles within a spiral channel, 10-μm particles were flown at a large range of flow rates (0.1-5.5 mL/min) for given channel geometry and radius of curvature. As illustrated in FIGS. **33**A-**33**C, particles remain focused over a wide range of R_c, and the focused particle trains are progressively displaced laterally away from the inner wall with increased R_c. These results support the theory and indicate the important role the secondary Dean flow plays in influencing the lateral displacement of single-stream focused particles over a wide range of R_c. As the R_c is increased beyond a certain value for a given channel geometry and particle size, the Dean drag becomes more dominant than inertial lift and the single stream focused particles start to drift away from the inner wall to form multiple-stream band of focused particles, as shown in FIG. **33**B. Further increase in R_c leads to complex fluid behavior disrupting the band and mixing. This suggests there is an upper limit on D_e above which particles start to mix due to dominant Dean flow. In addition to D_e, particle size to channel geometry ratio and radius curvature is a strong influence on particle behavior.

[0243] To investigate the relationship between various parameters affecting focusing of particles, different flow experiments with varying particle sizes and channel geometries were conducted. We tested a range of particle diameters (2-15-μm) and channel geometries (D_h 55-183-μm and radius of curvature 1.4-9.5 mm) for R_c values ranging from 4 to 700. FIG. **33**C shows the results of lateral displacement of focused particles plotted as a function R_f for the different conditions tested. The data is normalized and all calculations were based on n=−0.43. The results indicate that, although the magnitudes differ, the various parameters affect the balance of Drag forces and inertia lift in similar fashion, which is in good agreement with the theoretical prediction. High value on the y-axis indicate $F_z \gg F_{drag}$, resulting in smaller lateral displacement of the focused particles from the inner wall. This is accomplished by focusing a particular particle size at low R_c or by increasing the radius of curvature for a given R_c. Increase in R_c or decrease in radius of curvature result in lateral displacement away from the inner wall.

[0244] To investigate lateral displacement of focused particles in detail, different particle sizes were mixed and tested at various flow rates. At low flow rates, 10-μm and 7-μm particles are focused at the same streamline, indicative of inertia lift dominating over Dean drag, as shown in FIGS. **34**A and **34**B. As R_c increases, both particle sizes are pushed away from the inner wall, in agreement with an increased contribution from Dean drag that is predicted, as discussed earlier. However, the smaller particles are affected more by the increase in R_c in comparison to the larger particles and consequently drift away into a new equilibrium position further away from the inner wall. This new equilibrium position is independent of the presence of larger particles. Thus for a given channel geometry and R_c, the particles will always focus at a predicted equilibrium position.

Example 18

[0245] Referring to FIGS. **35**A-**35**F, separation applications based on differential equilibrium displacement within a spiral microfluidic device can be demonstrated. A cocktail mixture of particles (10, 7, 5 and 3-μm) were flown through a microfluidic spiral device with a channel depth of 50-μm with two outlets. One of the outlets was a channel of 50-μm wide and the other one was 950-μm. According to the theory and experimental findings, this specific dimension should allow the 10, 7 and 5-μm beads to focus while the 3-μm beads remain unfocused for any given R_c. As shown in FIGS. **32**A-**32**F, increasing the flow rate pushes the 7 and 5-μm beads away from the inner wall, while the 10-μm beads are intact focused in a single streamline closest to the inlet and can be